CENTER OF GRAVITY AND DIMENSION MEASURING DEVICE AND APPARATUS

Cross Reference to Related Application

[0001] The present application is a continuation application of U.S. Patent Application No. 10/226,376 filed August 22, 2002, now U.S. Patent No. 6,690,995 issued February 10, 2004, which itself claims priority to Application No. 60/314,770, filed August 24, 2001. The present application claims the benefit and priority of both of these applications to the fullest extent provided by law, and incorporates by reference the contents of each application.

[0002]

[0003] Technical Field

[0004] The present invention relates generally to the field of conveying and sorting and, more particularly, to a method and apparatus for measuring the center of gravity of a package on a moving conveyor and then pushing said package proximate its center of gravity to divert it from the conveyor without inducing a significant rotation.

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[0005] Background of the Invention

[0006] Modern parcel delivery services typically rely upon automated sorting systems to quickly and accurately sort packages into defined groups for distribution and delivery. The demand for faster sorting is one of the driving forces behind current innovations in the field of automated parcel sorting. As sorting systems are required to process more and more packages per hour, the devices for conveying, sorting, and diverting packages are becoming more sophisticated.

[0007] The demand for high-speed sorting has also sparked a need for sorting systems that are capable of handling a wide variety of packages having different sizes, shapes, and weights. Generally, an automated sorting system that does not require pre-sorting of packages by hand into like-size groups, for example, can proceed to final sort much quicker and with less cost.

[0008] High-speed conveying and sorting of large numbers of packages presents a variety of technical challenges, especially when the size, shape, and weight of the packages vary widely. The orderly diverting of packages of different weights, for example, requires a diverter capable of gently exerting a force that is proportional to the measured weight of the package. Similarly, the orderly diverting of packages of different sizes and shapes requires a method and apparatus for determining the optimal pushing location on each package, according to its

particular size and shape, and a system to control the motion of the diverter at the appropriate time.

[0009] In a high-speed sorting system, it is advantageous to divert objects without causing them to topple, turn, or start spinning. Conveyors and other devices downstream work more efficiently when the entering objects are stable and proceed in an orderly manner. A rotating package can jam downstream devices, interfere with stacking operations, or slide off the side of a conveyor, for example. Delays and system shutdowns caused by a spinning package are expensive and may interfere with sequential processing.

[0010] The orderly diverting of selected packages from among a diverse group of sizes and shapes is further complicated by the presence of soft, flexible pouches. The flexible pouch typically has dimensions that are difficult to measure, edges that are difficult to define, and a host of other unique characteristics requiring special handling.

[0011] Thus, there remains a need in the art for a method and apparatus to sort and divert packages from a group of packages having widely diverse characteristics.

[0012] There is a further need for a method and apparatus to divert packages with improved accuracy.

[0013] There is a related need for a method and apparatus to calculate the approximate center of gravity of a package from measured characteristics.

[0014] There is also a need for a method and apparatus to sense and transmit data about an object to a controller configured to direct and control the movement of downstream sorting and diverting components.

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[0015] Summary of the Invention

[0016] The present invention overcomes deficiencies in the prior art by providing a method and apparatus for measuring and diverting objects from a moving conveyor based upon various measurements. Stated generally, the invention comprises an array of sensors to measure the object, a signal processor to calculate or assign the approximate center of gravity, a diverter, and an actuator in communication with the signal processor to move the diverter such that it pushes against the approximate center of gravity of the object.

[0017] More particularly described, the present invention provides a conveying apparatus for evaluating a plurality of parcels being conveyed thereon, the plurality of parcels having differing lengths, the plurality of parcels including a parcel, the apparatus comprising a first conveyor defining a first conveying surface and including an exit location, a first sensor configured for sensing the presence of a first parcel portion of the parcel while the parcel is on the conveying surface, the first sensor configured to provide a first sensor signal when the first parcel portion moves out of the sensing range of the first sensor due either to tilting of the parcel over the crest, or alternatively due to movement of the parcel along the first conveyor portion without tilting, the first sensor being a first distance from the exit location, a second sensor configured for sensing the presence of a second parcel portion of the parcel while the parcel is on the conveying surface,

the second sensor configured to provide a second sensor signal when the second parcel portion moves out of the sensing range of the second sensor due to tilting of the parcel over the crest, or alternatively due either to movement of the parcel along the first conveyor portion without tilting, the second sensor being a second distance from the exit location, the second distance being less than the first distance, and a signal processing device for receiving the first and second signals and for determining for each of the parcels if one of two conditions is met:

[0018] 1) a first condition in which the first and second sensor signals are generated within a predetermined time;

[0019] 2) a second condition in which the first and second sensor signals are not generated within the predetermined time, the signal processing device providing a different output regarding parcel length depending on whether the first or second condition is met.

[0020] In another aspect of the invention, the inventive system is configured to actuate a diverter at a time when the cleats of the diverter will push against the approximate center of gravity of the object.

[0021] Therefore, it is an object of the present invention to provide an improved conveying system which provides improved sorting characteristics.

[0022] It is a further object of the present invention to provide an improved conveying method and apparatus which increases sorting capacity.

[0023] It is a further object of the present invention to provide an improved conveying method and apparatus, which recognizes differences in, parcel flexibility.

[0024] It is a further object of the present invention to provide an improved conveying method and apparatus, which recognizes differences in, parcel size, particularly length.

[0025] It is also an objective of the present invention to provide an improved method and apparatus that calculates or approximates the approximate center of gravity of an object based upon the measured characteristics.

[0026] It is a further object of the present invention to provide an improved conveying method and apparatus which diminishes rotation of the parcel during ejection of the parcel from the belt.

[0027] It is an further object of the present invention to provide an improved conveying and sorting system that diverts selected objects from a group of objects having widely diverse sizes and shapes.

[0028] It is further object of the present invention to provide a system for sensing and transmitting data about an object to a controller that is configured to direct and control the movement of downstream sorting and diverting components such that the

diverting of various size objects may be accomplished without inducing unwanted rotation.

[0029] These and other objectives are accomplished by the method and apparatus disclosed and will become apparent from the following detailed description of a preferred embodiment in conjunction with the accompanying drawings in which like numerals designate like elements.

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[0030] Brief Description of the Drawings

[0031] Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein like numerals indicate like elements throughout the several views:

[0032] **Fig. 1** is a perspective view of the conveying and diverting system **10** of the present invention, with an exemplary item, parcel or package **200** shown thereon.

[0033] **Fig. 2** is a top view of the diverting system **10** of the present invention. The item **200** of Fig. 1 is not shown.

[0034] **Fig. 3** is a side illustrative view of a portion of the apparatus which includes the tilt sensor group **30** and the tilt roller **25**.

[0035] **Fig. 4** is a view similar to Fig. 3, in which a “flexible” or “more flexible” item (a.k.a. “flexible pouch”) **500** is passing by the tilt sensor group **30** of the present invention, thus obstructing (a.k.a. “covering” or “triggering”) sensors **31**, **32**, **33**, and **34**. It should be understood that the flexibility of the item **500** allows the concurrent triggering of sensors **32** and **34**, whereas a more rigid (a.k.a. “less flexible”) parcel would not (it would tilt out of range of **31** before triggering **34**).

[0036] **Fig. 5A** is a view similar to Fig. 3, in which a “long” package **1000** is entering the tilt sensor group **30** and crossing the tilt roller **25** between the inclined conveyor **20** and the first

horizontal conveyor **40**. Sensors **31** and **32** are triggered, whereas sensor **34** is not.

[0037] **Fig. 5B** is a view similar to Fig. 5A, in which the long package **1000** has tilted over the tilt roller and landed on the first horizontal conveyor **40**. Sensor **34** is triggered, whereas sensors **31** and **32** now are not.

[0038] **Fig. 6A** is a view similar to Fig. 3, in which a "medium" length package **2000** has entered the tilt sensor group **30** and crossed the tilt roller **25** between the inclined conveyor **20** and the first horizontal conveyor **40**. As may be seen, sensor **31** is uncovered although the package has not yet tilted (it has been conveyed out of range of **31**). Sensor **32** is covered, whereas sensor **34** is not.

[0039] **Fig. 6B** is a view similar to Fig. 6A, except that the medium package **2000** has tilted and landed on the first horizontal conveyor **40**. Sensors **31** and **32** are uncovered and sensor **34** is covered.

[0040] **Fig. 7A** is a side view similar to Fig. 3, except that a short package **3000** has entered the tilt sensor group **30** and has crossed the tilt roller **25** between the inclined conveyor **20** and the first horizontal conveyor **40**. Sensors **31**, **32**, and **34** are all uncovered at this point in time, although sensor **33** is triggered.

[0041] **Fig. 7B** is a view similar to Fig. 7A except the short package has tilted and landed on the first horizontal conveyor **40**.

Nevertheless, sensors **31**, **32**, and **34** are all uncovered at this point in time, although sensor **33** is triggered.

[0042] **Figs. 8A and 8B** are illustrative diagrams of an object **200** in motion at different locations on an inclined plane and a horizontal plane, shown in progression to demonstrate a method of the present invention.

[0043] **Fig. 8A** is a block diagram of an object **200** at the moment its leading edge **220** reaches the crest between the inclined plane and the horizontal plane.

[0044] **Fig. 8B** is a block diagram of an object **200** in a relatively unstable position at the moment its center of gravity is positioned directly above the crest between the inclined plane and the horizontal plane.

[0045] **Fig. 9** is a block diagram of the control features of the system **10** of the present invention.

[0046] Detailed Description of the Drawings

[0047] Referring now in more detail to the drawings, in which like numerals indicate like elements throughout the several views, **Fig. 1** is an illustration of the measuring and sorting apparatus **10** according to the present invention.

[0048] The conveying and diverting system (or apparatus) **10** includes the following elements and subelements:

[0049] inclined induction conveyor assembly **20**

inclined induction conveyor belt **21**

angle **24**

idling tilt roller **25**

[0050] tilt sensor group **30**

first sensor **31**

second sensor **32**

third sensor **33**

fourth sensor **34**

[0051] first horizontal conveyor assembly **40**

first horizontal conveyor assembly belt **41**

[0052] width sensor group **50**

trigger sensor **51**

vertical curtain sensor **52**

[0053] second horizontal conveyor assembly **60**

second horizontal conveyor assembly belt **61**

[0054] diverter assembly **70**

diverter belt **71**

diverter cleat **72**

actuator **75**

diverter trigger **77**

[0055] discharge conveyor assembly **80**

discharge conveyor belt **81**

discharge conveyor driving mechanism **83**

[0056] collection area **100**

[0057] The following packages (a.k.a. parcels or items) are discussed by means of example:

object package **200**

long package **1000**

medium package **2000**

short package **3000**

flexible package **4000**

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[0058] General Construction and Operation

[0059] Generally described, the apparatus **10** as shown in **Fig. 1** includes an upwardly inclined induction conveyor **20** leading to a horizontal conveying assembly. The horizontal assembly may include a series of conveyors. In one preferred embodiment, the horizontal elements include a first horizontal conveyor **40**, a second horizontal conveyor **60**, and a third horizontal conveyor **80**. An idling tilt roller **25** (a.k.a. "tilting roller") is positioned in a gap between the inclined conveyor **20** and the first horizontal conveyor **40**. A group of sensors known as the tilt sensor group **30** is positioned proximate the tilt roller **25** to sense and transmit data about the object **200** being conveyed. Another group of sensors known as the width sensor group **50** is positioned near the gap between the first horizontal conveyor **40** and the second horizontal conveyor **60**. A diverter **70** is positioned in the gap between the second horizontal conveyor **60** and the third horizontal conveyor **80**.

[0060] In one aspect of the present invention, the diverter **70** is configured to divert an object **200** by contacting the object with a diverter cleat **71** (or another suitable diverting element) as the cleat moves towards the approximate center of gravity of the object **200**. This center of gravity (a.k.a. **"CG"**) is based upon object data gathered by the plurality of specifically placed upstream sensors. This approximated "CG" can be derived via actual measurement or by estimation.

[0061] The tilt sensor group **30** senses data about the object **200** (a.k.a. parcel, package, or item) as it passes over the tilt roller **25** including data relating to the size and relative rigidity of the object, as well as the CG of the object. The width sensor group **50** measures the width of the object **200**, as well as its lateral location on the second horizontal conveyor **60**.

[0062] The sensor data is transmitted to a signal processor **90** that, in turn, controls an actuator **75** to move the diverter **70** such that it pushes against the approximate center of gravity of the object **200**, thereby diverting the object **200** off the conveyor with minimal rotation.

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[0063] The Inclined Conveyor 20

[0064] The inclined conveyor assembly **20**, as shown in **Fig. 1**, includes an endless conveyor belt **21** which is moved along an endless path around powered and idler rollers supported by a frame and driven by a motor or other suitable drive means (noted as 23 in Fig. 9) in a manner that is known in the art.

[0065] The supporting surface of the inclined conveyor belt **21** ramps upward at an angle **24**. In one embodiment, the angle **24** may be ten degrees above horizontal, although other angles and inclined configurations are contemplated according to the present invention. The angle **24** shown in the figures may be exaggerated for clarity. This supporting surface could be considered to lie along a first supporting surface plane.

[0066] The inclined conveyor assembly **20** accepts parcels or other items from an outside source, such as by hand or from another conveyor, and delivers the parcels toward the idling tilt roller **25** and subsequently onto a first horizontal conveyor **40**. In one embodiment, it is preferred that the parcels are placed "square" on the induction belt **21**.

[0067] It should be understood that the belt conveyor system described above could be replaced with a powered roller or other suitable conveyor under an alternate version of the invention.

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[0068] The Tilt Roller **25**

[0069] At the discharge end of the inclined conveyor assembly **20** is located an idling tilt roller **25**, which includes an elongate shaft mounted to the frame **11** of the apparatus **10** in a manner that allows rotational movement about the longitudinal axis of the tilt roller **25**, caused by movement of the conveyed objects. This provides what shall be referred to in this application as a "rolling tilt", in that tilting is done as the tilted item rolls across a supporting member (in this case member **25**). This roller **25** shall also be understood to provide a "crest", over which parcels tilt.

[0070] As noted above, the tilt roller **25** is in one embodiment an idling roller, in that it is not powered. Instead, it includes two opposing pins which extend in opposing directions and which function as stub shafts, in that they are free to rotate within upwardly-directed slots (not shown) defined by the frame of the apparatus. There are two such slots, one corresponding to each stub shaft, with each slot positioned on one side of the conveying path. This stub shaft/slot configuration allows the tilt roller **25** to be "dropped in" without the use of tools. The pins and slots could include suitable bearings or bearing material as needed.

[0071] It should also be understood that a powered roller could be used in place of an idling roller under an alternate invention.

[0072] The tilt roller **25** and the inclined conveyor could be considered to be part of a conveyor assembly also including

conveyor assembly **20**, as they convey parcels along a plane which could be considered a first supporting surface plane.

[0073] The tilt roller **25** could also be considered a "crest" over which relatively rigid parcels tilt over and away from the first conveyor **20** (flexible parcels will be discussed separately). Relatively rigid parcels passing over said crest portion tilt over said crest portion as a unit and away from said first conveyor. It may be seen that during the initial tilting the trailing portion of the parcel moves upwardly and away from the conveying surface; this is one way the system recognizes tilting is occurring, assuming other restrictions are met.

[0074] It should be understood that under an alternative configuration under the present invention, instead of using a tilting roller to provide said tilting, no tilting roller could be used, and the parcels could tilt off the end of the first conveyer **20** and the end of the conveyor **20** could be considered the "crest".

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[0075] The First Horizontal Conveyor 40

[0076] The first horizontal conveyor assembly **40** includes an endless first conveyor belt **41** which is moved along an endless path around powered and idler rollers supported by a frame and driven by a motor (or other suitable drive means) (noted as **43** in Fig. 9) in a manner that is known in the art.

[0077] The first horizontal conveyor **40** moves objects **200** from the tilt roller **25** towards the width sensor group **50**, and transfers such objects to the second horizontal conveyor **60**.

[0078] It should be understood that the belt conveyor system described above could be replaced with a powered roller or other suitable conveyor under an alternate version of the invention.

[0079] It should also be understood that if no distinction is being made between an inclined conveyor and a horizontal conveyor, conveyor **20** could be considered a "first" conveyor and conveyor **40** could be considered a "second" conveyor.

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[0080] The Second Horizontal Conveyor **60**

[0081] Still referring to **Fig. 1**, the second horizontal conveyor **60** includes an endless second conveyor belt **61** which is moved along an endless path around powered and idler rollers supported by a frame and driven by a motor (or other suitable drive means) (noted as **63** in Fig. 9) in a manner that is known in the art.

[0082] The second horizontal conveyor **60** moves objects **200** from its entry end (proximate the width sensor group **50**) towards its exit end, proximate the diverter assembly **70**.

[0083] As an object **200** moves toward the end of the second horizontal conveyor **60**, it passes a diverter trigger sensor **77** shown in **Fig. 1** to alert the system **10** of the arrival of the object **200** at the diverter **70**. Using the known velocity of the second horizontal conveyor **60**, the system **10** of the present invention uses the activation of the diverter trigger sensor **77** to "double-check" the location of the object **200**.

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[0084] The Third Horizontal Conveyor **80**

[0085] The third horizontal conveyor **80** includes an endless discharge conveyor belt **81** which is moved along an endless path around powered and idler rollers supported by a frame and driven by a motor (or other suitable means) (a.k.a. a "discharge conveyor driving mechanism **83**") in a manner that is known in the art.

[0086] The third horizontal conveyor **80** accepts and conveys objects **200** that pass from the second horizontal conveyor **60** over the diverter **70** without being diverted.

[0087] It should be understood that the belt conveyor system described above could be replaced with a powered roller or other suitable conveyor under an alternate version of the invention.

[0088] Diverter 70

[0089] As shown in **Fig. 1**, the diverter assembly **70** of the present invention in one embodiment is positioned between the second horizontal conveyor **60** and the third horizontal conveyor **80**. The diverter **70** may include an endless narrow diverter belt **71** which is moved along an endless path transverse to the moving direction of conveyors **60**, **80**, and driven by a servo driven actuator motor ("actuator **75**") that controls the direction and velocity of the diverter belt **71**.

[0090] In one preferred embodiment, the diverter **70** of the present invention uses a modified bilateral sorter similar to the type disclosed in commonly-owned U.S. Patent No 6,204,042, issued July 24, 2001, which is incorporated herein by reference. The bilateral sorter may include an endless narrow belt having two spaced-apart sections where a series of cleats such as **72** are affixed to the narrow belt. The cleats are designed to carefully and gently push an object being diverted.

[0091] The narrow belt of the bilateral sorter has a home position and an edge or "ready" position. The edge position represents the location of the narrow belt such that the first of the cleats is positioned close to where the near side edge of the footprint of the object **200** will pass when it reaches the bilateral sorter **70**. Based upon the known location of the near side edge, the actuator **75** places the narrow belt of the bilateral sorter **70** at the edge position, to pre-position the narrow belt and ready the

system to divert the object **200**. This diversion is accomplished by contact of the cleat(s) with the surface which extends upwardly from the near side edge.

[0092] It should be understood that the narrow belt **72** may be activated to push against the surface which extends upwardly from the near side edge or the surface which extends upwardly from the far side edge, depending upon the discharge side selected for the object **200**. Alternatively, the narrow belt **72** may be directed to remain at the home position so as to allow the object **200** to proceed directly onto the third horizontal conveyor **80**. In this manner, the diverter **70** and its controls determine in which of three possible directions the object **200** will be conveyed.

[0093] The home position represents the neutral position of the narrow belt **72**, where the narrow belt **72** returns when not in active use. The narrow belt **72** in one preferred embodiment includes two cleated sections along its length and two uncleated sections spaced therebetween. Either uncleated section can be used as a home position. Including two cleated sections and two uncleated sections reduces by half the time it takes for the narrow belt **72** to move to one of the available home.

[0094] It should be understood that the ejection system described above could be replaced with an alternate ejection system under an alternate configuration of the invention.

[0095] <u>Tilt Sensor Group **30**</u>

[0096] As shown in **Fig. 3**, the tilt sensor group **30** includes a first sensor **31**, a second sensor **32**, a horizontal curtain sensor **33**, and a fourth sensor **34**. In one preferred embodiment, these sensors are through-beam photoelectric sensors, although other sensor types are contemplated according to the present invention.

[0097] In one preferred embodiment, the tilt sensor group **30** is arrayed as shown in **Fig. 3** such that the first and second sensors **31**, **32** are positioned upstream from the tilt roller **25**, and the fourth sensor **34** is positioned downstream from the tilt roller **25**.

[0098] In one embodiment not that should be construed as limiting, the first sensor **31** is about 6.00 inches (15.24 cm) upstream from the vertical curtain sensor **33**, the second sensor **32** is about 2.75 inches (6.99 cm) upstream from the vertical curtain sensor **33**, and the fourth sensor **34** is about 3.00 inches (7.62 cm) downstream from the vertical curtain sensor **33**.

[0099] The first sensor **31** could also be considered a "first tilt initiation sensor", as that is one of its functions. The second sensor **32** could likewise be considered a "second tilt initiation sensor". The fourth sensor **34** could likewise also be considered a "first tilt completion sensor". The operation and use of these sensors **31**, **32**, and **33** will be discussed in later detail. The horizontal curtain sensor **33** is mounted beside the tilt roller **25** with its sides in a substantially vertical orientation to measure the

length of an object **200** as it passes. In one embodiment the light curtain **33** is a bank of aligned horizontal individual sensors, but they are configured with suitable controls to function as a single sensor. In other words, if any of the horizontal beams is broken, the sensor will be considered triggered.

[00100] The plane of the inclined conveyor passes above the lowest sensor in the light curtain and below the next-to-lowest sensor in the light curtain.

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[00101] Width Sensor Group **50**

[00102] Referring again to **Fig. 1**, as an object **200** moves along the first horizontal conveyor **40** toward the second horizontal conveyor **60**, the object **200** passes by a trigger sensor **51** and then through a vertical curtain sensor, which may also be referenced as a profiling assembly **52**. The profiling assembly **52**, in one preferred configuration, may include an array of discrete photoelectric sensors which are used to determine the overall width of the object **200**, and its lateral position on the conveyors **40**, **60**. As will become apparent, the lateral position is useful in determining the location of the near and far side edges of the object **200**. The object **200** moves from the first horizontal conveyor **40** onto the second horizontal conveyor **60** as it passes through the profiling assembly **52** positioned between the two conveyors.

[00103] System Control

[00104] **Fig. 9** is a functional block diagram of the controls of the system **10** of the present invention. In one preferred embodiment, the system **10** is controlled by a first controller **90** and a second controller **92**. In general, the first controller **90** gathers information from the various sensors, while the second controller **92** sends information to the diverter actuator **75** and/or the discharge conveyor driving mechanism **83**.

[00105] The curtain sensor **52** includes its own internal controller **52-C**, which reports to the first controller.

[00106] In one aspect of the system **10** of the present invention, the inclined conveyor driving mechanism **23** drives the inclined conveyor **20** at a constant velocity, and provides a signal representative of such velocity to the first controller **90**. Similarly, the first and second horizontal driving mechanisms **43**, **63**, respectively, drive the first and second horizontal conveyors **40**, **60**, respectively, at a constant velocity, and provide a signal representative of such velocities to the first controller **90**. As may be understood, the conveyor velocity **vx** is an important variable used in estimating the CG location. Preferably these two conveyors run at the same speed.

[00107] The system **10** continuously monitors the conditions of the photoelectric sensors **31** through **36** and **77** to determine whether they are in a blocked or unobstructed condition.

[00108] General Function of Tilt Sensor Group

[00109] It should be understood that the tilt sensor group in conjunction with the present invention is capable of evaluating various physical characteristics of the conveyed objects. One feature of the invention allows for the determination of whether the parcel is relatively rigid or relatively flexible. If the parcel is determined to be relatively rigid, under another feature of the invention its length is evaluated to determine if the parcel is long, medium or short (in length). Depending on the determined length of these rigid packages, different types of CG determination or assignment rules may then be applied to these packages.

[00110] As noted above, the tilt sensor group **30** shown in **Fig. 3** includes a first sensor **31**, a second sensor **32**, a third sensor **33** and a fourth sensor **34**. These sensors may be used in conjunction with other sensors without departing from the spirit and scope of the present invention. As will be noted from discussion elsewhere, the first sensor **31** could also be considered a "first tilt initiation sensor", the second sensor **32** could be considered a "second tilt initiation sensor", and the fourth sensor **34** could likewise also be considered a "first tilt completion sensor".

[00111] It may be also be understood that if the first and second sensors both sense a particular parcel, these sensors will be sensing different, spaced apart, portions of the same parcel. Therefore it may be said that the first sensor will be sensing a first

parcel portion and the second sensor will be sensing a second parcel portion. The same applies for the other sensors.

[00112] Flexibility Evaluation

[00113] Under one method according to the present invention, the tilt sensor group **30**, in conjunction with other control elements, is used to determine if a parcel is "flexible" relative to a pre-established standard. This standard can vary from apparatus to apparatus, but generally speaking does not vary for a given apparatus assuming the position and sensitivity of the sensors is not changed.

[00114] As will be discussed in further detail below, the use of a tilting process in conjunction with tilting sensors is used for parcels which are rigid enough to "tilt" (or roll) over the idling tilt roller **25**. However, the present invention also accommodates the use of "bags", which, unlike traditional rectangular parcels made of cardboard or the like, tend to be more flexible, and do not "tilt". Since such tilting cannot be provided, the system accommodates this by providing two sensors and suitable controls. Under one embodiment of the present invention this includes sensors **32** and **34**, which as may be seen are on opposite sides of the idling tilt roller **25**. The system will recognize that a flexible package is being processed when sensors **32** and **34** both recognize the presence of a package/parcel/item at the same time. As may be understood, when both such sensors recognize the presence of a parcel at the same time, the system according to the invention will

assume that the parcel is “flexible” so as to bend over the idling tilt roller **25**.

[00115] As shown in **Fig. 4**, an exemplary object shape is determined to be flexible if certain photoelectric beams emitted by sensors **32** and **34** are obstructed by the object at the same time. A flexible pouch **500** for example will obstruct the second sensor **32** and the fourth sensor **34** simultaneously (and if long enough may also obstruct sensor **31** as shown). Conversely, a rigid object such as a typical parallelepiped cardboard box will not obstruct sensors **32** and **34** at the same time when traveling over the tilt roller **25**, because of the angle of inclination.

[00116] Once an item is assumed to be “flexible”, it is assumed that it will not pivot. The method then assigns a predetermined estimated location to the CG along the length of the item. Under one embodiment of the present invention, this is assumed to be a percentage of the length of the item. In one particular embodiment of the present invention, this percentage is assumed to be 40%, in that a flexible parcel ten inches long will be assumed to have a CG located four inches from its leading edge. This is an empirically determined amount which can be varied as needed.

[00117] Package Size (particularly length) Evaluation

[00118] In another aspect of the invention, inflexible object size is determined to be long, medium, or short. Each size is treated differently in the determination (which includes assignment) of CG.

[00119] For a "long" package **1000**, as depicted in Figs. 5A and 5B, the photoelectric beams emitted by the first sensor **31** and the second sensor **32** will be uncovered at approximately the same time (or within a preselected time period which can be selected as desired by the programmer) when a suitably long package **1000** tilts over the tilt roller **25**. Thus the system of the invention assumes that a parcel is long if the first and second sensors are uncovered (a.k.a. "untriggered") within a preselected time period. As may be understood this programmed period could be varied as needed, such as if different belt speeds are used, or if typical package characteristics are varied, and thus a particular time period cannot be stated as being preferred.

[00120] For a medium length package **2000**, as depicted in Figs. 6A and 6B, or for a short length package 3000 as shown in Figs. 7A and 7B, the photoelectric beam emitted by the first sensor **31** will be uncovered (although not due to tilting) while the second sensor **32** remains obstructed.

[00121] In order to distinguish between a medium package **2000** and a short package **3000**, the fourth sensor **34** is used in conjunction with system controls. Particularly, the timing of the

uncovering of the second sensor **32** is compared to the timing of the covering of the fourth sensor **34**. If these events both occur within a certain predetermined period of time (again which can vary depending on the system and can be selected during setup or programming of the system) the system assumes that the parcel has tilted from the position shown in Fig. 6A to the position shown in Fig. 6B and thus is a medium length package **2000**. If instead these events do not occur within a certain period of time, then the scenario as shown in Fig. 7A and 7B will have assumed to occur, resulting in a determination of a short package **3000**.

[00122] It should be understood that the time periods discussed above can be different depending on the types of items which are being processed by the apparatus, depending on the speed at which the apparatus is operating, depending on the sensitivity of the sensors, depending on the desired definition of "long", "medium" or "short", or depending on a variety of other variables.

[00123] In this manner, the size of the object **200** is estimated by the three sensors **31**, **32**, **34**, in conjunction with system controls, and the system assigns an object size of long package **1000**, medium package **2000**, or short package **3000**.

[00124] Under one method of the present invention, the determination of a long package **1000**, medium package **2000**, or short package **3000** results in the assignment of a CG value by three different methods. This assignment can be by evaluation of

the tilting characteristics or the packages or by assignment of CG by empirical methods, without evaluating tilting characteristics.

[00125] In the case of a short package, the CG is simply assigned to be in the middle of the package. Thus no tilting evaluation is made; the measured length of the package is all that is needed. This is done by the light curtain **33** in conjunction with the known belt speed. However, it should be understood that the horizontal light curtain **33** information is buffered so that it can be used in case a short package is processed (which the system wouldn't know until after the light curtain was broken).

[00126] In the case of medium and long packages, an estimation of the CG location is made as described in more detail below by "evaluating tilting"; in other words by sensing at what time the packages begin and complete their tilt over the idling tilt roller **25**.

[00127] In the case of medium packages, sensor **32** will be used to sense the beginning of package tilt. In the case of long packages, sensor **31** will be used to sense the beginning of package tilt, although it may be understood that sensor **32** will also be uncovered at approximately the same time. This is recognized as one important invention in that it may be understood that the further the sensor is from the tilting location, the more accurate the measurement of tilting; thus the invention optimizes the use of the two sensors **31**, **32**. In both cases, the light curtain sensor **33** is used to determine how far the parcel has passed over the idling tilt roller **25** when they begin their tilt.

[00128] Therefore it may be seen that the invention allows for the use of the two first sensors **31** and **32** for tilting evaluation, but when possible, for purposes of accuracy, allows for the use of the furthest available upstream sensor being uncovered by tilting.

[00129] <u>Center of Gravity Measurement, Tilting</u>

[00130] One method of the present invention measures the approximate location of the center of gravity (CG) of an object **200** by evaluating its tilting characteristics over the idling tilt roller **25.** Once the parcel has passed over the roller **25**, it should be understood that a center of gravity component has been determined. This center of gravity component is only in one axis, which will be presumed for purposes of this discussion in the "x" axis, which will also be presumed for purposes of this discussion to be the axis along which the package is traveling from the beginning to the end of the overall conveyor system. Thus the center of gravity calculation will be presumed to be a certain distance from the leading edge of the parcel. This distance is determined from recognizing from at what point the package "tilts" after its leading edge has been passed over the pivoting roller.

[00131] As may be understood, an object **200** that is transported up the inclined conveyor **20** and onto the first horizontal conveyor **40** will start to tilt when its CG passes over the tilt roller **25** at the crest. The present invention uses a series of sensors to measure the distance between the leading edge **220** of an object **200** and the approximate longitudinal position of the CG. Using the approximate CG location, a diverter **70** positioned downstream from the sensors is actuated to push against the CG of the object **220**.

[00132] **Figs. 8A and 8B** are block diagrams that are useful in demonstrating the basic principle of the inventive method. The x-y axis is centered about the leading edge **220** of the object **200**. The weight **W** of the object **200** is shown acting through the center of gravity (CG). The x-y axis is fixed with respect to the object **200** and, therefore, moves and rotates with the object **200** as it moves and rotates.

[00133] **Fig. 8B shows the object 200 at the approximate moment when the CG** is located directly above the crest between the inclined plane and the horizontal plane (the package will be assumed to have just begun its tilt). At this location, the distance **b** is the x-coordinate of the CG. The objective of the present invention is to calculate this distance **b** for the object **200**.

[00134] Referring to the block diagrams in **Figs. 8A and 8B**, the system of the present invention, in one aspect, uses the known speed **vx** of the conveyors and the various times at which certain sensors are tripped to measure data about each object **200**. In one aspect of the present invention, the vertical curtain sensor **33** (shown in **Fig. 8A**) first senses the leading edge **220** of the object **200** at a time defined as **T1**. At the moment in time depicted in **Fig. 8B**, the object **200** has begun to tilt (clockwise) such that all three sensors **31**, **32**, **34** are unobstructed. This moment in time is defined as **T2**. The difference between **T2** and **T1** is used by the inventive method to calculate the distance **b** for the object **200** being measured. In one preferred embodiment, the time **T1** is set

to equal zero seconds such that the time **T2** alone represents the time needed to calculate the distance **b**.

[00135] In a related aspect of the present invention, the method of calculating the distance **b** begins from the known laws of motion; specifically, distance equals velocity times time. Because of the angle of inclination and the fact that an object's weight **W** is always exerted vertically downward, the method of the present invention first calculates the distance **a** shown in **Fig. 8B**. Applying the laws of motion to the block diagram in **Fig. 8B**, and using the known speed **vx** of the conveyors, the distance **a** equals **vx** times the difference between **T2** and **T1**.

$$\mathbf{a = vx * (T2 - T1)}$$

If **T1** equals zero seconds, the distance **a** equals **vx** times **T2**.

[00136] It will be appreciated by those skilled in the art that there is a difference between the distance **a** and the distance **b**. The distance **b** is shorter than the distance **a**. In **Fig. 8B**, the difference between the distance **a** and the distance **b** is labeled as the distance **c**.

[00137] In one aspect of the present invention, it has been observed that the distance **c** varies depending upon the angle of inclination and the velocity **vx** of the conveyors. As the conveyor velocity **vx** increases, the distance **c** increases.

[00138] In a related aspect, the method of the present invention includes a distance known as a correction factor **cf** which has been determined experimentally using objects with known CG locations and known weights. The correction factor **cf** is a function of the conveyor velocity **vx**, the angle of inclination, and the weight **W** of the object **200**. For example, for an angle of inclination of ten degrees and a conveyor velocity **vx** of 150 feet per minute (45.72 meters per minute), the correction factor **cf** is 1.00 inches (2.54 cm). At the same angle, for a conveyor velocity **vx** of 300 feet per minute (91.44 meters per minute), the correction factor **cf** is 2.50 inches (6.35 cm). For a conveyor velocity **vx** of 450 feet per minute (137.16 meters per minute), the correction factor **cf** is 4.00 inches (10.16 cm).

[00139] It has been observed that the correction factor **cf** is an approximation of the distance **c** that is sufficiently accurate to result in a reliable calculation of the distance **b**. Recalling from **Fig. 8B** that **b** equals **a** minus **c**,

$$\mathbf{b} = \mathbf{a} - \mathbf{c}$$

using the calculation set forth above for the distance **a**,

$$\mathbf{b} = [\ \mathbf{vx} * (\mathbf{T2} - \mathbf{T1})\ ] - \mathbf{c}$$

and using the correction factor **cf** in place of the distance **c**,

$$b = [\, vx * (T2 - T1)\,] - cf$$

the distance **b**, indicating the position of the CG of the object **200**, can be calculated with sufficient accuracy. In one preferred embodiment where **T1** equals zero seconds, the calculation becomes,

$$b = [\, vx * T2\,] - cf$$

where **T2** is measured by the sensors of the present invention, **vx** is the known conveyor velocity, and **cf** is the correction factor that corresponds to the angle of inclination and the known conveyor velocity.

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[00140] Diverter 70 Pre-Positioning

[00141] In a further aspect of the system **10**, the profiling assembly **50** is in communication with the first controller **90**. The profiling assembly **50** senses both the overall width of the object **200** and the location of the near side edge of the object **200**, which for purposes of this discussion will be assumed to be the side opposite the collection area **100** of Fig. 2. The profiling assembly **50** transmits a signal to the first controller **90** representative of such measurements.

[00142] The second controller **92**, using data from the first controller **90**, is configured to direct the diverter actuator **75** to pre-position the narrow belt **71** of the diverter **70**. The pre-positioning task occurs when the object **200** is sensed by the diverter trigger sensor **77**. The pre-positioning task moves the belt **71** from a home position to an edge position. The edge position represents the location of the narrow belt **71** such that the first of the cleats **71** is positioned close to where the near side edge of the object **200** will pass when it reaches the diverter **70**. Based upon the known location of the near side edge, the actuator **75** places the narrow belt **71** of the diverter **70** at the edge position, to pre-position the narrow belt **71** and ready the system to divert the object **200** to the collection area **100**.

[00143] Overall Process from Start to Finish

[00144] The overall process will now be restated in light of the above discussion of particular elements.

[00145] As noted above, the sorting of diverse packages requires a host of sensors and controllers to smoothly activate a variety of auxiliary devices positioned along the conveyor, such as the diverting mechanisms that move a selected package off a conveyor. Smooth diverter actuation requires extensive data about the parcel being diverted, especially when the diverter is called upon to move packages of different sizes, shapes, and weights.

[00146] A parcel is first placed on this inclined conveyor by hand or automation, and is introduced proximate the tilt sensor group **30**.

[00147] The horizontal curtain sensor **33** of the tilt sensor group **30** transmits a signal to the first controller **90** when it senses the presence of a parcel at a time **T1**. **T1** is preferably set to zero when the signal is received, such that receipt of the signal starts a timer running in a manner similar to a stopwatch. The other three sensors **31**, **32**, **34** also are used for sensing as discussed above.

[00148] The tilt sensor group **30** thus senses data about the parcel as it passes over the tilt roller **25** including data relating to the size and relative rigidity of the parcel, as well as the CG of the parcel. When the parcel has passed the tilt sensor group **30**, all

information needed to assign the center of gravity has been taken.

[00149] The width sensor group **50** then measures the width of the parcel, as well as its lateral location on the second horizontal conveyor **60**. The parcel then approaches the diverter.

[00150] If the parcel is to be diverted sidewardly, sensor data is transmitted to a signal processor **90** that, in turn, controls an actuator **75** to move the diverter **70** such that the diverter **70** diverts the parcel by contacting the parcel with a diverter cleat **72** (or another suitable diverting element) as the cleat moves towards the approximate center of gravity of the parcel. This center of gravity (a.k.a. **"CG"**) is based upon object data gathered by the plurality of specifically placed upstream sensors. This approximated "CG" can be derived via actual measurement or by estimation, as previously discussed. Preferably the cleat pushes against the approximate center of gravity of the parcel, thereby diverting the parcel off the conveyor with minimal rotation.

[00151] If the item is not to be diverted, the parcel passes over the diverter untouched.

[00152] Conclusion

[00153] While this invention has been described in specific detail with reference to the disclosed embodiments, it will be understood that many variations and modifications may be effected without departing from the spirit and scope of the invention as described in the appended claims.